SECTION I: Executive Summary

Our analysis of General Aviation (GA) accidents that occurred during the decade of the 1990s (Goh & Wiegmann, 2002) indicated that the fatality rate of accidents involving visual flight rules (VFR) flight into instrument meteorological conditions (IMC), or unqualified flight into adverse weather, was consistently higher than that of other GA accidents. The fatality rate of VFR into IMC accidents was approximately 80% during this period compared to approximately 19% for other types of GA accidents. These statistics reflect similar trends found by the National Transportation Safety Board (1989) for U.S. GA accidents that occurred during the 1970s and mid-1980s, as well as GA accident trends in other countries (e.g., United Kingdom and New Zealand). Together, these findings clearly indicate that VFR flight into IMC continues to be a major safety hazard within General Aviation (O'Hare & Smitheram, 1995).

Visual flight rules flight into IMC is often characterized by pilots' decisions to continue a flight into adverse weather conditions, despite having been given information or presented with cues that indicate they should do otherwise (NTSB, 1989). Our laboratory studies (e.g., Goh & Wiegmann, 2001; Wiegmann, Goh & O'Hare, 2002), suggest that VFR pilots who continue simulated flights into adverse weather generally misinterpret weather information, overestimating weather parameters (i.e., have more positive views of cloud ceiling and visibility) than those who do not continue VFR flight into IMC. Pilots involved in VFR-IMC accidents also generally have less experience diagnosing and flying in adverse weather (Goh & Wiegmann, 2002). Burian et al. (2000) found that pilots in their study who were in the 25th percentile and below in terms of total flight hours were more likely to press on into deteriorating weather than those in the 75th percentile and above. The authors suggested that some pilots, particularly those with less experience, "do not trust what their eyes are telling them and so proceed on blindly" (p.

25). Therefore, at least in some situations, VFR flight into IMC can be viewed as a failure in recognition-primed decision-making (RPD; Klein, 1993). Consequently, training and technological inventions that focus on improving pilots' situation awareness (SA) and weather evaluation might improve pilot decision making, thereby reducing accidents due to VFR flight into IMC.

Contrary to the above evidence, however, are findings indicating that some pilots occasionally choose to continue flight into adverse weather even after they have become aware of the hazardous conditions (Burian et al., 2000). Pilots who continue flight into adverse weather tend to be overconfident in their abilities and also underestimate the risks of VFR flight into IMC (O'Hare, 1990). Indeed, results from some of our laboratory research (e.g., Goh & Wiegmann, 2001) partially support this hypothesis in that pilots who chose to continue a simulated flight into adverse weather were more confident in their skills and generally underestimated the risks of crashing due to the weather. Our findings, as well as the findings of other researchers in this area, indicate that prior exposure to adverse weather may improve pilots' situation assessment abilities (Wiggins & O'Hare, 1995; O'Hare, Owen & Wiegmann, 2001), but it also reduces their perceptions of risk (i.e., increases their risk tolerance; Goh & Wiegmann, 2003). Therefore, on subsequent encounters with adverse weather, they may be more willing to press on into the weather and thus more likely to fly into conditions that exceed their abilities. Consequently, these findings suggest that training and intervention technologies designed to improve weather-related decision-making also need to be evaluated in terms of their potential impact on risk-taking behavior.

Unfortunately, to date only a few empirical studies have been conducted to examine the impact that different types of technology aboard aircraft have on pilots' decisions to continue

VFR flight into IMC. For example, O'Hare, Owen and Wiegmann (2001) found that pilots flying an airplane equipped with a global positioning system (GPS) were more accurate in their situation awareness but were also more likely to continue flight into deteriorating weather and remain airborne longer than those who flew aircraft without GPS equipment. Beringer and Ball (2003) found that pilots provided with onboard weather information using NEXRAD (NEXt-generation-RADar) displays had better assessments of weather conditions than those having only "out the window" (OTW) weather information. However, NEXRAD also increased risk-taking behavior, with the highest resolution displays encouraging pilots to continue flights with the expectation that they could fly around or between significant weather features. These findings suggest that as weather and other navigation displays become more advanced and sophisticated (e.g., highway in the sky [HITS] and synthetic vision [SVS] displays), they may shift pilots' decision making processes from that of *strategic* decision-making (attempting to avoid the hazard altogether) to that of *tactical* decision-making (negotiating a path through a weather hazard area such as a broken line of thunderstorms). Such shifts in decision-making strategies could have severe negative ramifications for generally less-skilled GA pilots.

The specific parameters of advanced displays that impact pilot-decision making have yet to be systematically identified. Hence, little is known about how to design displays to achieve their desire effect (e.g., improved weather evaluation) while *also* minimizing any detrimental impact they have on decision-making (i.e., induced risk taking). It should be noted, however, that the impact that advanced cockpit displays have on decision-making and risk-taking behavior is likely to be affected by individual differences in pilot personalities and experiences. As stated previously, flight experience (including overall flight time, cross country flying, and recency), self-confidence, and risk-taking tendencies can all influence pilots' weather-related decision-making (Goh & Wiegmann, 2002). Novacek et al. (2001) found that pilots who possessed more extreme risk-taking personalities were also more likely to make riskier/poorer weather-related decisions when using a NEXRAD display than those pilots who were generally risk averse. Hence, further research projects need to examine the impact that advanced displays have on decision-making in the GA cockpit, while also considering individual differences in pilots' experiences and risk-taking tendencies.

Finally, the majority of research and interventions have focused on addressing the causes of VFR flight into IMC but not the consequences. Naturally, the impetus to understand the reasons why a pilot might continue flight into adverse weather is so that preventive measures can be developed. However, often overlooked, at least within the GA environment, is the fact that VFR flight into IMC results in an accident because pilots quickly become spatially disoriented due to a lack of any clear visual horizon. Our research indicates (e.g., Goh & Wiegmann, 2002) that pilots involved in VFR-IMC accidents have fewer flight hours and are less likely to be instrument rated. Hence, these pilots are not capable of transitioning to instrument flight once they become disoriented. As a result, they lose control of the aircraft and fatally crash. Consequently, additional research is needed to develop methods to address the consequences of VFR flight to IMC (i.e., spatial disorientation and loss of control), at least within the GA environment.

Conclusions and Recommendations

1. Conclusion: The rate and severity of VFR flight into IMC accidents has remained high since the NTSB's report on VFR-IMC accidents that occurred in the mid-1970s and 1980s. These results suggest that interventions have been unsuccessful in curbing pilots' decision to continue VFR flight into adverse weather conditions.
    a. Recommendation: Identify and reevaluate safety programs currently in place to address VFR flight into IMC.
2. Conclusion: Our studies suggest that VFR pilots who continue simulated flights into adverse weather generally misinterpret weather information and generally have less experience diagnosing and flying in adverse weather.
    a. Recommendation: Interventions that focus on improving pilots' weather interpretation and evaluation, as well as in-flight planning need to be developed.
3. Conclusion: Some pilots occasionally choose to continue flight into adverse weather even after they have become aware of the hazardous conditions. Pilots who continue flight into adverse weather tend to be overconfident in their abilities and also underestimate the risks of VFR flight into IMC.
    a. Recommendation: Interventions that focus on improving pilots' understanding and appreciation of the risks involved with VFR flight into IMC need to be developed.
4. Conclusion: Some interventions that have been developed to improve weather-related decision-making may also have a negative impact, at least in some situations, by increasing pilots' confidence in their ability to safely navigate

through adverse weather.

a. Recommendation: Interventions *must* be systematically developed and empirically evaluated to determine their impact on decision-making behavior. Otherwise, counterproductive effects could occur.

5. Conclusion: Most intervention research has focused on addressing the causes of VFR flight into IMC but not the consequences. Often overlooked, at least within the GA environment, is the fact that VFR flight into IMC results in pilots becoming spatially disoriented due to a lack of any clear visual horizon. As a result, they lose control of the aircraft and fatally crash.

    a. Recommendation: Additional research is needed to develop methods to address the consequences of VFR flight to IMC (i.e., spatial disorientation and loss of control), at least within the GA environment.

Overview of the Remaining Document

The remaining sections in this report contain the numerous articles and presentations generated from this project. These materials provide a detailed description of the methods, results, conclusions, and recommendations associated with these efforts. The sections are organized in the following order:

1. Peer-reviewed Journal Articles
2. Technical Reports
3. Conference Presentations
    a. proceedings articles
    b. published abstracts
    c. presentations without published proceedings/abstracts
4. Thesis Abstract

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